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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

This Issue

LUBRICATING OIL PROCESSING DEVELOPMENT

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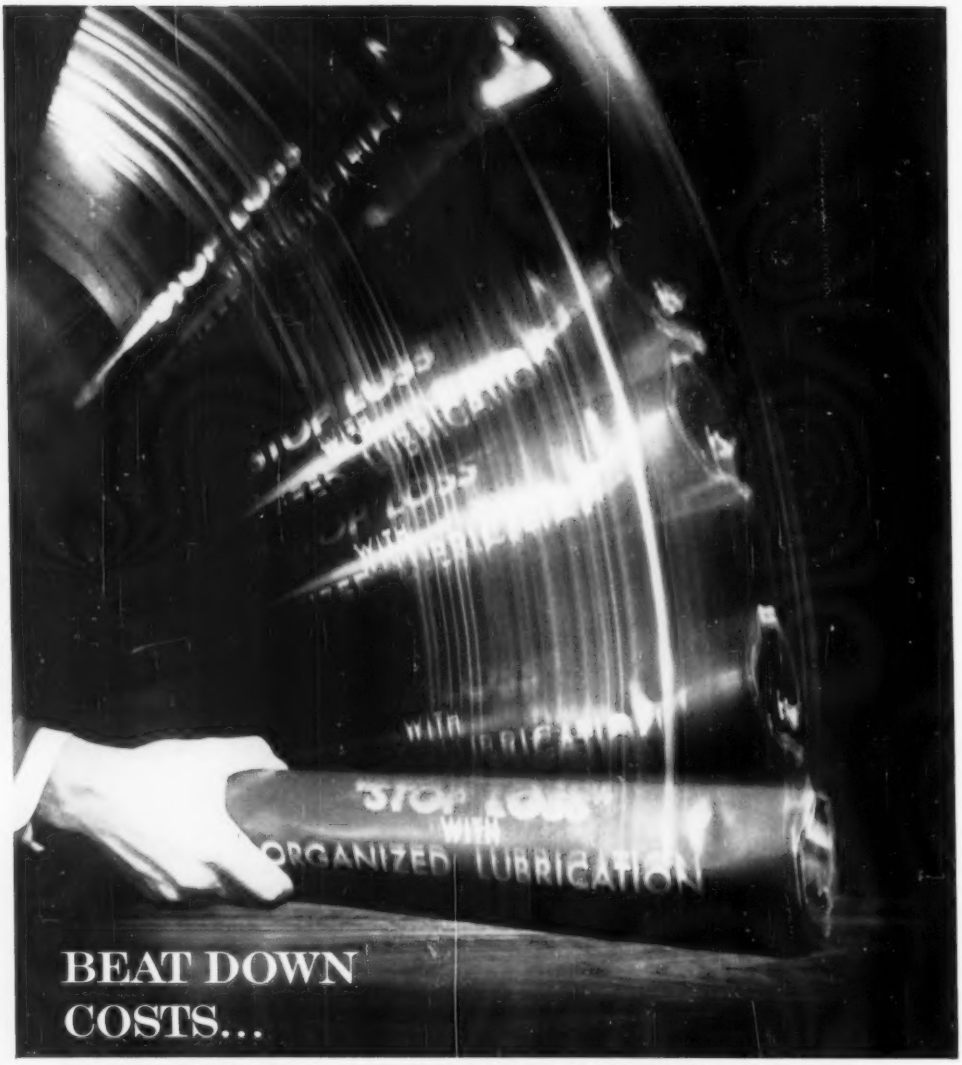

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LUBRICATION

A TECHNICAL PUBLICATION DEVOTED TO THE SELECTION AND USE OF LUBRICANTS

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Lubricating Oil Processing Development

After eons of residence in the earth, crude petroleum oil (or "crude") is a very raw material, principally composed of varying proportions of: various gases; gaseous, liquid and solid hydrocarbons; water; salt; sand; crystalline and amorphous hydrocarbon waxes; oxygenated materials such as asphalts; small amounts of free and chemically combined sulphur, arsenic, sodium, vanadium and other extraneous metals.

For most purposes the hydrocarbons (chemicals containing only hydrogen and carbon) in the crude mixture are the most suitable and most desired, but there are literally hundreds of these in several chemical configurations with differing properties.

Thus the petroleum refiner's problem is simply stated but most difficult to perform: to "process" (i.e. economically separate, classify, purify, reform and/or reinforce) selected portions of crude oil into a bewildering variety of chemicals and chemical mixtures, each of which is designed to be best suited to a particular use. Petroleum chemistry is among the most abstruse divisions of that science.

A large refiner producing a complete line of lubricants must have a continuing active development program on lubricating oil processing. It is by such processing that selected portions of crude oils are transformed into finished products tailored to customer's requirements. There are three facets of a processing development program:

1. As new crude oils are discovered, processing evaluations are performed to select crudes which are suitable for lubricating oil manufacture and to establish the type and degree of refining needed to produce highest quality products at minimum cost.

2. As existing refining processes are improved through research, the same high product quality is maintained or improved, possibly while reducing the cost.

3. As new processing methods are developed, these advances are translated into new products to meet the ever-increasing severity of new applications.

The lubricating oil user is generally not familiar with this work because of its behind-the-scenes nature. However, he has a direct interest in the results since they insure that he will be supplied with products of uniformly high quality to meet his needs.

QUALITY BASE OILS

A previous issue[1] of this publication has described the extensive research necessary to develop a new automobile motor oil. The first objective in such research is to obtain a sufficient quantity of a base oil of adequate and rigidly controlled quality at a reasonable cost. If (as is frequently true) the performance of the straight-mineral base oil is not high enough, an "additive package," i.e., a balanced mixture of effective additives, is then developed in the

[1] Magazine Lubrication; December, 1958; "Development of a New Motor Oil."

laboratories to impart or improve certain critical performance characteristics of this specific base oil.

Since the effectiveness of a given quantity of an additive depends not only on its own qualities, but also those of the base oil and associated additives, and since synergistic (mutually helpful) effects are desirable, the complex process of fitting all the components of an oil to each other requires extensive (and expensive) research and development work.[2]

After the "additive package" has been developed, extensive service testing of the new motor oil, including several types of road tests, is necessary. Only after this testing has conclusively demonstrated the improved performance of the oil is the product ready for marketing. Then, manufacturing facilities for the various additives must frequently be constructed. Thus, a new motor oil ready for marketing represents the end result of a very sizable investment in time, research personnel effort, and specialized manufacturing facilities.

The development and proof testing of lubricants other than automobile motor oils follows the same general course, but is complicated by the fact that a given base oil may be used in many different lubricants, each designed for a specific type of equipment. Since all of these lubricants may contain different additives tailored to the base oil, it is essential that the quality of the base oil not be allowed to fluctuate.

The refiner's problem of maintaining base oil quality is complicated by several factors:

1. He must often use crude oils which vary in composition. The crude oil from one formation (depth) in an oil field may be different from that obtained from another formation in the same field and may also vary as production continues. One oil well may tap two or more formations, and the ratio of production from the formations may vary with time.

2. The rate at which an oil field produces crude tends to decline as the field grows older. Base oils are often developed from some specific crude. Thus, the day will inevitably come when there will not be enough of that particular crude to manufacture all of the base oil needed. Crude from another, perhaps newly discovered, field must then be used to make the base oil. This newer crude will almost certainly have a different composition than the original.

3. In order to insure maximum recovery of crude oil in the ground, some state regulatory agencies in the United States require that total crude oil requirements be prorated among the many separate oil fields. Therefore, no field is required to produce at a rate higher than necessary to permit protecting its share of the total market. This factor may limit the availability of certain crudes used for base oils. Here again, a different crude, having a different composition, may have to be used to supplement the original.

Whenever varying crude composition threatens to affect base oil quality, compensating processing changes must be made. These changes might merely be simple modifications of the processing conditions used. However, major changes in the crude might mean that new processing steps must be inserted into the sequence for manufacturing the base oil. Whether the changes are minor or major, extensive quality evaluations are required to insure that the new base oils are equivalent or superior to the old ones as components of the various products.

Some of the more important base oil properties that must be rigidly controlled to insure constant final product quality are discussed in the following.

Viscosity

The viscosity or fluidity of a lubricant is its most important single property. Since viscosity and volatility are inversely proportional, vacuum distillation is used to divide a given crude oil into *fractions* or *streams*, each having a desired viscosity. Each fraction is then subjected to the particular processing procedures which will convert it into a base oil of the desired quality. High vacuum is used during distillation to reduce temperatures and thereby minimize any thermal decomposition (or "cracking") of the future lubricating oil. The viscosity of any fraction may be increased or decreased by subsequent processes, blending and additives, yet the viscosity of the finished lubricating oil must fall within narrow limits. Consequently the processing engineer must exercise considerable forsight and planning on this one property alone.

Viscosity-Temperature Relationship

All base oils tend to "thicken," or increase in viscosity, as their temperature is lowered. Viscosity Index[3] (VI) is a convenient measure of this tendency since an oil of high VI thickens less than one of a lower VI. The Viscosity Index or viscosity temperature characteristic of a base oil is determined both by the characteristics of the crude oil and the processing used in manufacturing it. A base oil having a high viscosity index is usually manufactured more economically from a crude oil of similar characteristic.

A lubricant that must function over a wide range of temperatures should have a high viscosity index. For example, a motor oil is normally required to lubricate at a relatively high operating temperature since cylinder wall temperatures may be in the range of 320°F., and crankcase temperatures about 180°F. However, the same oil must also lubricate the engine during starting at temperatures of perhaps 0°F., or even lower in cold climates. If the oil thickens too much on cooling from 180° to 0°F., it

[2] Magazine Lubrication: March, 1957: "Additives with a Purpose."

[3] Magazine Lubrication: January and February, 1961: "Viscosity"

will not allow the engine to be started nor lubricate it satisfactorily thereafter. For this reason, base oils used for motor oils and many other lubricants must have a certain minimum viscosity index. If the oil is to be used at constant temperature, as in stationary power plants, viscosity index is less important.

Though additives can be used to improve the VI of a lubricant, its base oil must still have a certain minimum VI and must be responsive to a reasonable quantity of the selected VI additive. Base oil VI is controlled by processing as discussed later in this article.

Thermal and Oxidation Stabilities

When the rather large molecules in a base oil are over-heated, either in the presence or absence of oxygen or air, they tend to either break apart or reform into undesirable decomposition products which may be acidic (and thus promote corrosion) or carbonaceous or varnish-like (which promote wear and deposits), or a combination of these.

The thermal and oxidation stabilities of a base oil can be controlled considerably by the processing operations used in its manufacture, as will be discussed later in this report. Additives which inhibit oxidative decomposition are often included in the additive package of a lubricant.

Color and Color Stability

Color is not generally considered to be a critical property of a base oil, however, many of the processes used for manufacturing base oils also improve color along with some other more critical property such as oxidation stability or additive response. Since color is more easily or more quickly measured than some of these properties, it is often used as a secondary manufacturing control. For instance, after establishing that a base oil processed to a certain color level in a given processing operation exhibits the desired level of performance, product color specifications can be set which will assist in maintaining that quality. Any variation in color will signal some change, such as processing equipment malfunction, which may also be adversely affecting base oil quality, and which deserves further, more extensive investigation.

Color stability is often used in the same manner. If a base oil tends to darken excessively in storage, it may be an indication that some other, really-important property is also being affected adversely. Base oil samples are often stored at elevated temperatures to accelerate the evaluation of color stability.

Reasonable constancy of color in the finished lubricant is also desirable since some users regard color as a measure of quality, and it is certainly one of the few that they can readily check.

In some lubricants a light initial color may be advantageous not only because of its esthetic appeal, but also because darkening during use may indicate ingress of harmful contaminants and thus permit corrective action before real damage occurs.

Cloud and Pour Points

Both the amorphous and crystalline types of paraffin wax are composed of several paraffinic type hydrocarbons which occur naturally and to greater or lesser extent in most petroleum oils. If such oils are chilled sufficiently, visible crystals of paraffin wax begin to form and the temperature at which this is observed is called the oil's *cloud point*. Sometimes an oil can be used at temperatures below the cloud point since the presence of tiny wax crystals does not necessarily impede lubrication. Often, as in automobile engines, the cloudy oil will clear up due to the wax going back into solution as soon as the engine warms up slightly. In other uses, the cloud point of the oil must be below the operating temperature. This is the case whenever the oil is required to flow through small passageways, such as those found in certain types of hydraulic and refrigeration equipment, which could be clogged by even small amounts of wax crystals.

Wax crystals will continue to grow on further chilling and may eventually completely solidify the oil. Other non-crystalline hydrocarbons in the oil also increase their viscosity so rapidly with temperature reduction as to cause apparent solidification. In either case, the *pour point* is the lowest temperature at which the oil will pour or flow under definitely prescribed laboratory test conditions.

In most lubricating oil applications, the pour point of the oil must be below the operating temperature to insure satisfactory flow of the oil to the surfaces requiring lubrication.

Wax may be removed from a base oil, thus improving both its cloud and pour points, by some process such as solvent dewaxing which will be discussed in more detail later in this article. Several additives are also available to depress the pour point of a finished lubricant below that of its base oil. In practice, it is usually desirable to use *both* methods, that is to remove the bulk of the wax from the base oil by dewaxing, then to use a pour point depressant in the finished lubricant for further pour reduction to the desired level. Pour point depressants do not prevent wax separating from the oil (and therefore do not affect its cloud point), but they do inhibit the subsequent crystal growth and thereby lower the temperature at which oil solidification occurs.

Some base oils, made from crude oils that were already essentially wax-free, may not exhibit a cloud point upon chilling to reasonably low temperatures. However, their viscosities will increase on chilling until they become so high that the oils will not flow and are, for all practical purposes, solids. Therefore, even oils from wax-free crudes have pour points, but they cannot be reduced by dewaxing or by

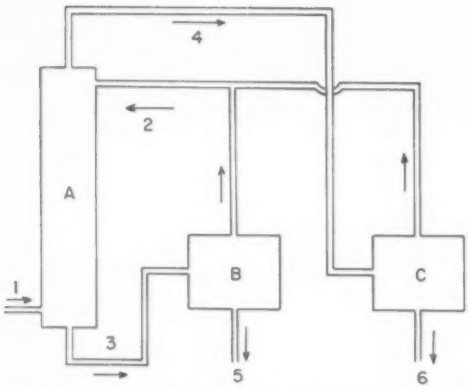

Figure 1 — Schematic flow diagram of furfural refining process. Raw oil (1) enters counter-current extraction tower (A), is thoroughly mixed with furfural (2), leaves top of tower as raffinate (4). Furfural is distilled off of raffinate in recovery unit (C) and recycled to tower (A) leaving refined oil (6). Recovery unit (B) similarly separates extract-furfural solution (3) into furfural (2) and extract (5).

adding pour point depressants since no wax is present. However, the pour point of such an oil can be reduced by processing to improve viscosity index so that the viscosity will not increase so much when the temperature is reduced.

Other Critical Properties

There are many other base oil properties that affect final performance and must be considered in any development program. While complete discussion of these is far beyond the scope of this short article, a partial listing follows:

Volatility

An oil's tendency to evaporate may be indicated by flash point but more precisely by its distillation curve. Low volatility is usually desirable.

Water Separation

Oils used in certain types of equipment, such as steam turbines, paper machines and rolling mills often become mixed with water in service. Before reuse, the oil should be separated from this water by settling, centrifuging and/or filtration. Oils intended for these types of service should separate quickly and cleanly from water and particularly avoid the formation of emulsions, therefore an emulsion test is used to measure this property.

Acidity or Alkalinity

Significant acidity or alkalinity in a straight-mineral base oil usually reflects the presence of small amounts of acidic or basic materials which might be corrosive or prone to oxidation. Essentially complete removal of such compounds is desired in processing and the neutralization number test provides a sensitive control on base oils.

However, the ordinary type of neutralization test can be most misleading if mistakenly applied to some *additive type* oils since the test reagents react with the additives themselves and thereby produce a false indication of acidity or alkalinity which is actually a measure of the amount of additive present.

CRITICAL PROPERTY CONTROL

A lubricating oil stock is usually separated from its crude oil by vacuum distillation. Only in rare instances are the properties of this *vacuum distillate* such that it can be used as a base oil without further treatment. On the contrary, the vacuum distillate stock must pass through several processing operations, designed to improve one or more qualities of the oil.

Some of the more important processes used singly or in combination during base oil manufacture are discussed in the following.

Solvent Refining

Several *selective solvents* are known which have the ability to dissolve and thereby remove undesirable components of a lubricating oil stock without affecting the desirable components. Furfural is one of the most effective and widely used of these solvents; the furfural refining process has been described in detail in a previous issue of this magazine.[4]

Furfural is a heavy nonviscous, low boiling liquid while a lubricating oil stock is generally lighter (in specific gravity) and more viscous than furfural. In the furfural oil refining process, the furfural is *contacted* (intimately mixed) with the oil in a *countercurrent extraction tower*, a tall, hollow column which may be "packed" with small rings to obtain more complete mixing. Oil is continuously pumped into the tower near its bottom, while furfural is continuously pumped into the tower near its top and (being heavier than the oil), falls down through the oil and the packing to the bottom of the tower. Thus, the countercurrent tower not only keeps the oil in continual contact with the furfural, but also subjects the purest oil emerging from the top of the column to the purest furfural which enters the column at that point. The undesirable material which dissolves in the furfural and is removed from the oil is called *extract:* the refined oil which did not dissolve in the furfural is called *raffinate*. The volume of extract removed from a given charge oil depends primarily on the type of charge oil but can be increased by using more furfural, or by contacting the oil and furfural at a higher temperature. As they leave the bottom and top of the column respec-

[4] Magazine Lubrication; December, 1946; "Solvent Refining and Dewaxing of Lubricating Oil."

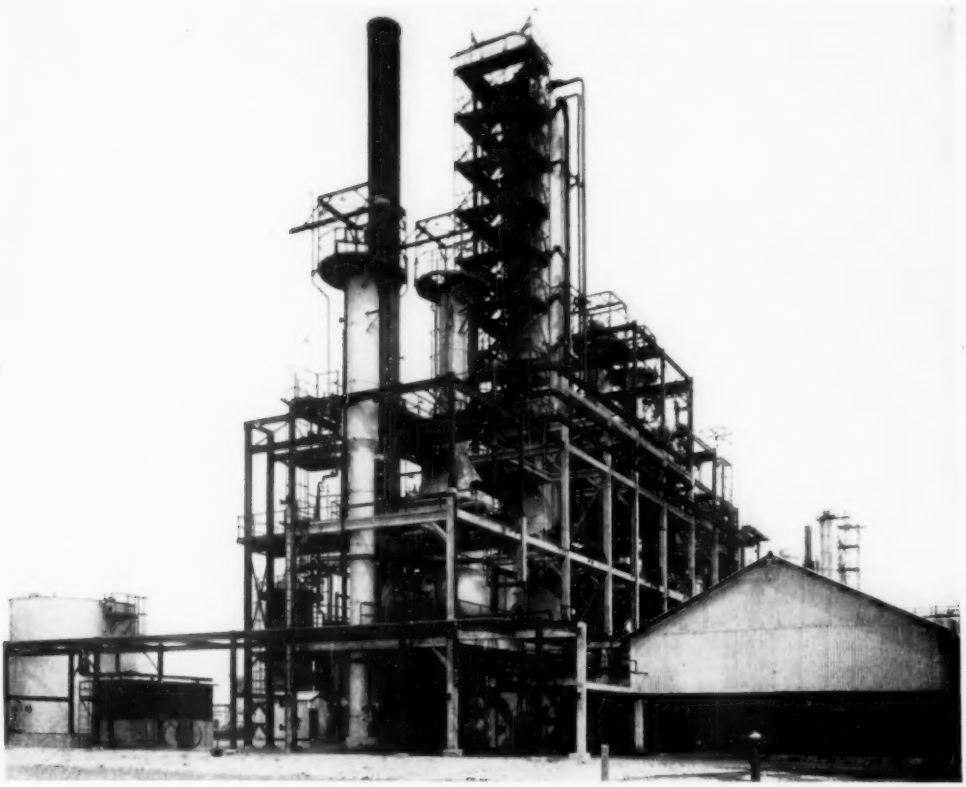

Figure 2 — A modern furfural refining unit.

tively, both the extract and raffinate contain furfural which is removed in a subsequent stripping (distillation) operation and returned ("recycled") to the tower for further use. Though the oil-containing raffinate is the desired end product of this process, the extract contains valuable by-products which are recovered and used in manufacturing other materials. Figure 1 shows a simplified flow diagram of the process while Figure 2 illustrates an actual modern furfural refining unit, which is a large and intricate chemical processing plant.

Furfural refining improves viscosity index, thermal and oxidation stabilities, viscosity-volatility relationships, color and many other qualities of a lubricating oil stock. Thus, if a lubricating oil stock from a certain crude is deficient in these respects as compared to a stock from some other crude, the deficiency can be overcome by refining under more severe conditions but with consequent reduced yield and increased cost.

Acid and Clay Treating

Lubricating oil stocks are often treated with either sulfuric acid or adsorbent clays to remove small amounts of undesirable reactive materials and thereby improve color, color stability, thermal and oxidation stability, and water separating properties.

Sulphuric acid treating is usually carried out in large, cone-bottom tanks called agitators. The oil is added to the agitator and the acid is sprayed in while the oil is being vigorously agitated. The sulfuric acid reacts with the more reactive materials in the oil, forming a dense acid *sludge* which settles to the bottom of the agitator after mixing is discontinued. The sludge-free oil decanted from the agitator contains some oil-soluble acidic reaction products which are removed either by chemical neutralization and water washing, or by contacting with a special clay as discussed below.

There are two ways in which oils are contacted with adsorbent clay. In the *contact filtering process* the powdered clay is mixed with the oil, the resulting "slurry" heated, and the clay, with its absorbed impurities, is then filtered from the treated oil. The clay will also remove oil soluble acidic compounds from acid treated oils so these are sometimes charged to this process.

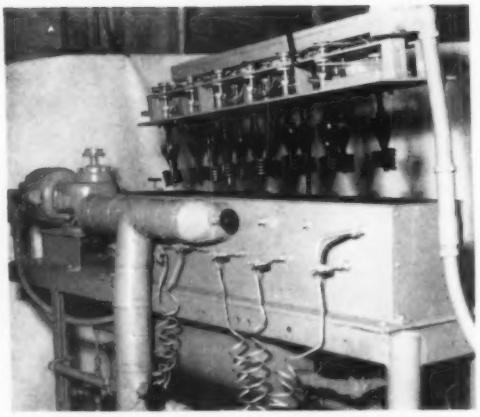

Figure 3 — Pilot plant furfural refining contactor.

Clay percolation is the other commonly used clay treating process. The oil is simply allowed to percolate or flow slowly down through a bed of solid, granular, adsorbent clay. Acid treated oils are not normally charged to this process without prior chemical neutralization.

Some base oils do not require acid or clay treating. Some are acid treated only. Others are acid treated and contact filtered. Still others might be acid treated, contact filtered and percolated. Some might be clay treated by one or both methods, but not acid treated. In all cases, the optimum procedure must be worked out for each base oil according to the properties desired in the final oil.

The degree of improvement obtained in either acid or clay treating is controlled primarily by the type and proportional amount of acid or clay used to treat a given volume of oil. If the quality of the oil changes due to some variation in crude, these controlling factors can be changed to insure that the quality of the final base oil is not affected.

Solvent Dewaxing

As discussed previously, base oils are dewaxed solely to improve cloud and pour points so that they can be used at lower temperatures. The widely used solvent dewaxing process has been described in detail previously.[5] Briefly, the waxy oil is dissolved in a special solvent generally consisting of a mixture of methylethyl ketone and toluene. Optimum solvent composition, and solvent-oil ratio, must be determined for each oil. The mixture is chilled, causing the wax to crystallize from the solution. The crystallized wax can then be filtered from the solution at a filtering temperature which is usually from 5° to 10°F. below the pour point desired on the finished base oil. The solvent is then removed by distillation from the dewaxed oil, and returned for reuse to the system.

Propane Deasphalting

Lubricating oils of very high viscosity are manufactured from *residuum*, the non-distillable portion of the crude oil which remains after the lighter and more volatile lubricating oil fractions have been distilled off. Residuum usually contains asphaltic materials of low viscosity index which must be removed before the oil is treated with any of the processes discussed in the foregoing.

The propane deasphalting process is now generally used on these heavy oils. The stock is contacted with liquid propane, often in a countercurrent tower similar to that used in furfural refining. However, the desirable lubricating oil dissolves in the propane while the asphalt does not. The process usually operates at 150° to 200°F., and since propane boils at minus 49°F. under atmospheric pressure the deasphalting tower must be operated under a higher pressure to keep the propane in its liquid state.

The amount of asphalt extracted from the stock can be increased by increasing the contacting temperature which provides a method of compensating for changes in crude oil composition. As in other solvent processes the propane is distilled from the asphalt and oil for reuse.

CRUDE OIL EVALUATION

Whenever a new crude oil is introduced, an extensive evaluation program is required to determine the best methods for making quality base oils from it. A similar program is required whenever the composition of a previously used crude changes. Such work is expensive and time consuming but is absolutely necessary to insure that final product quality is maintained.

Pilot plants, or small versions of the full size processing plants, are used extensively in work of this type. Lubricating oil stocks are run on these small units and the results used to predict how the stocks should be run in full-size plants. A laboratory doing crude evaluation work will have pilot plants which duplicate the functions of all the processes used in manufacturing base oils.

In a typical evaluation, a few gallons of the crude oil are distilled to obtain the raw lubricating oil fractions which correspond in viscosity to the base oils to be manufactured. Laboratory "test-tube" tests on these raw lubricating oil fractions are then obtained and compared to those desired in the base oils. With this information, the type and amount of processing required to transform them into the desired base oils can often be predicted with fair accuracy. For instance, if the raw stock has a lower viscosity index than needed it will probably require furfural refining, and the degree of improvement

[5] Magazine Lubrication; December, 1946; "Solvent Refining and Dewaxing of Lubricating Oil."

required will provide a basis for estimating the furfural dosage and temperature. Inspection of cloud and pour point data will show whether solvent dewaxing is necessary, and if so, the dewaxing yield can be estimated from the results of a simple wax analysis.

Pilot plant runs are then made to check the accuracy of the laboratory predictions. Results of these runs may show that the original estimates have to be modified, and additional pilot runs are then made to check the modifications. For instance, the base oil sample prepared in the first pilot unit run might have a lower viscosity index than desired. In this case, a higher furfural dosage and or temperature would be used in the second furfural refining run. As another example, the first sample of base oil prepared may be deficient in oxidation stability. Here several modifications might be considered, such as more severe furfural refining, acid treating or clay treating, together with possible use of an anti-oxidant additive in the finished oil. Sometimes it is found that such severe processing is required that the desired base oil costs more to make from the crude in question than it is worth on the market. In this case, the refiner is forced to either look for another crude which will not require such severe processing, or to develop an alternate, more economical method of processing.

Pilot unit equipment need not physically resemble the plant equipment it duplicates. For example, Figure 3 shows a pilot unit furfural refining contactor. Here, the furfural and oil are contacted in a series of chambers where they are mixed by the pulley-driven agitators shown. The mixing chambers are so interconnected, with intermediate settling chambers, that the furfural flows in one direction through the unit while the oil flows in the opposite direction. Thus, countercurrent contact of the oil and furfural is achieved just as in the packed towers of the full sized furfural refining unit shown in Figure 2. The two units show excellent agreement so that the pilot unit data can be used to establish processing conditions required on a plant unit.

The rate at which wax can be filtered from the mixture of dewaxed oil and solvent is one of the facts that usually needs to be determined before a new stock is run in the plant. Pilot plant work is done to establish the optimum solvent composition and the solvent-oil ratio to be used. Filter rate determinations can be made by using a small disc-shaped filter leaf of the type shown in Figure 4. This leaf is immersed in a container holding the slurry of wax, oil and solvent with a definite vacuum applied to the outlet for a measured time. The volumes of the dewaxed oil-solvent mixture thus drawn through the filter, and of the wax cake collected on the filter, are measured and used to calculate the filter rate. Filter rates determined on this simple apparatus correlate well with those obtained on full size plant filters.

After enough small scale pilot dewaxing unit runs have been made to establish the processing conditions required on a given oil, additional larger scale runs may be made in larger pilot dewaxing units to provide enough base oil for extensive field tests in the equipment for which the base oil is intended. Figure 5 shows a small rotary dewaxing filter, and Figure 6 a stripper used to distill and recover solvent from the dewaxed oil. These are miniature versions of the full size plant dewaxing equipment shown in Figures 7 and 8.

The pilot plant shown in Figures 5 and 6 can produce about 100 gallons of dewaxed oil per day. This unit might have to be run for several days to produce enough oil for testing required. For instance, the base oil might be used in products designed for crankcases of large diesel engines. If so, a product containing the new base oil will be extensively tested in a large diesel engine to insure that it is satisfactory for this service. This assurance is needed before plant manufacture of a new base oil is started. Tests in such a large engine require several hundred gallons of oil.

PROCESS IMPROVEMENT

Some of the base oil manufacturing processes, such as furfural refining and solvent dewaxing, have been successfully used for many years. However, re-

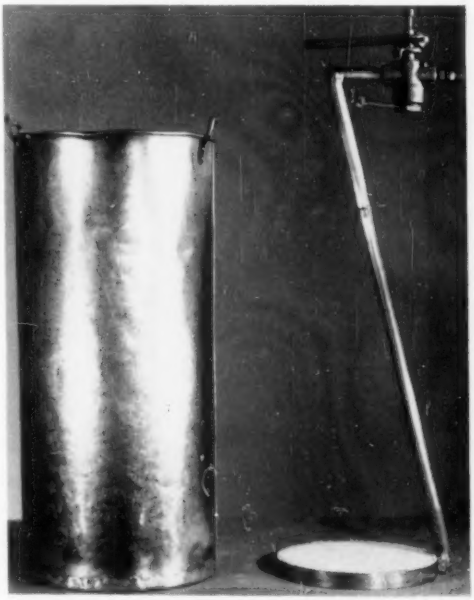

Figure 4 — Chilling can (left) and small stationary filter leaf (right) used in laboratory determination of oil dewaxing rate.

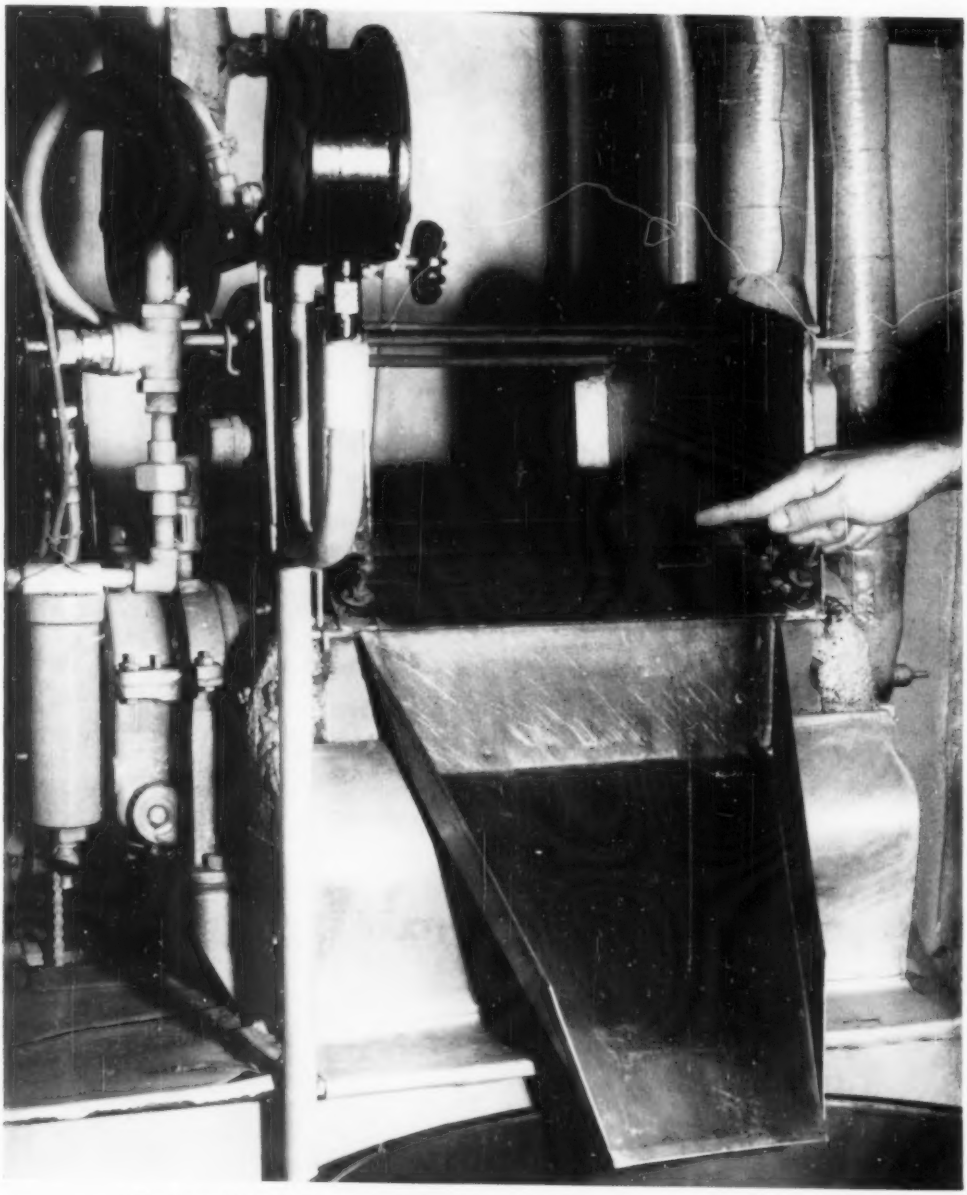

Figure 5 — Pilot plant rotary dewaxing filter (indicated by finger) with wax scraper and trough.

search on these processes is still being conducted to improve their efficiency and thus reduce manufacturing costs. An individual refiner must do this to remain competitive with other refiners. The lubricant user benefits since this assures him that high quality products will be available at minimum cost.

Figure 9 illustrates one of the changes that was made to the solvent dewaxing process to improve efficiency. In an early version of the process (shown schematically on the left side of Figure 9) waxy

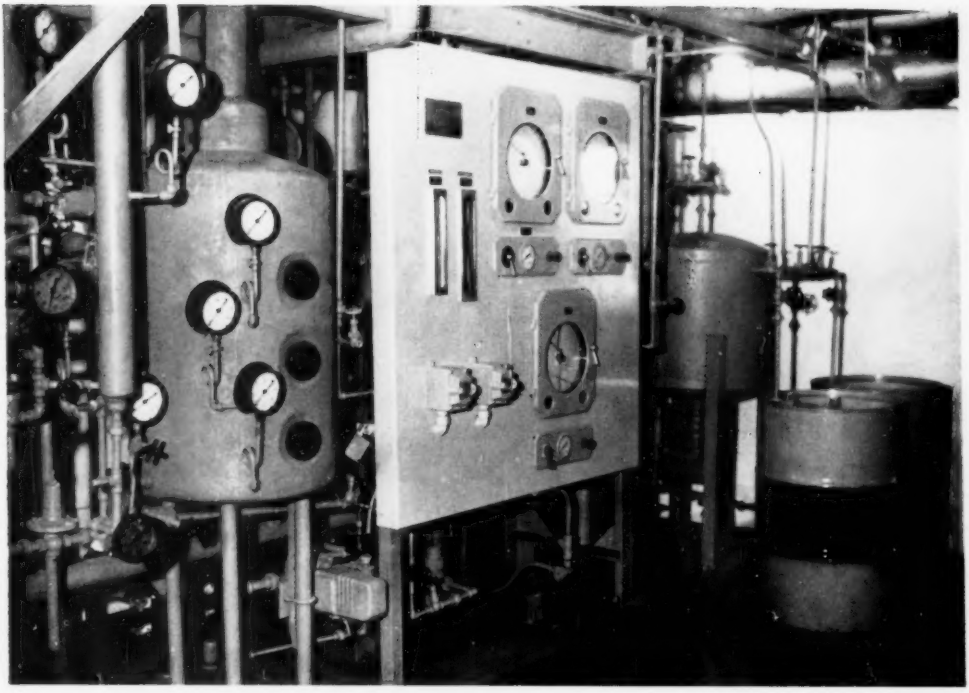

Figure 6 — Solvent strippers for pilot plant dewaxing unit shown in Figure 5.

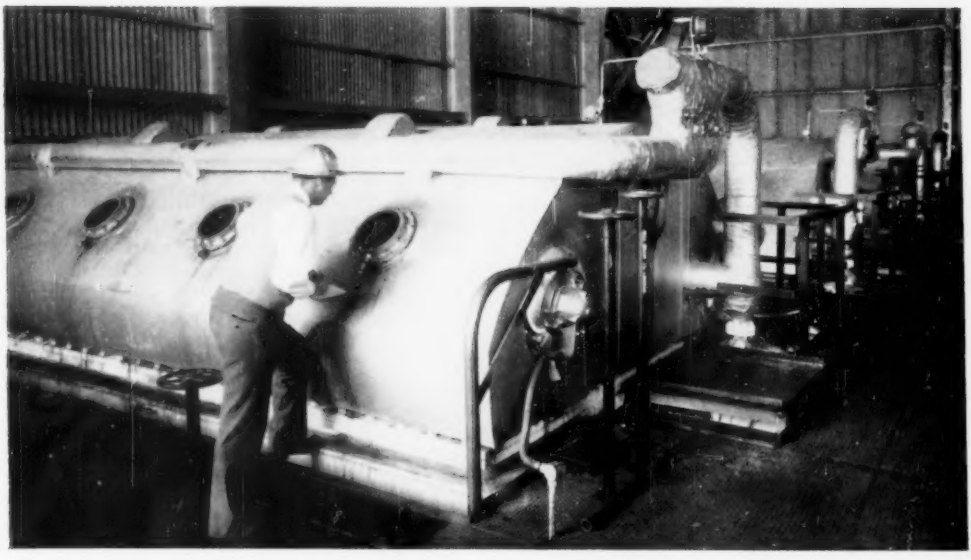

Figure 7 — Four plant-production rotary dewaxing filters, wholly enclosed to reduce solvent loss and consequent hazard.

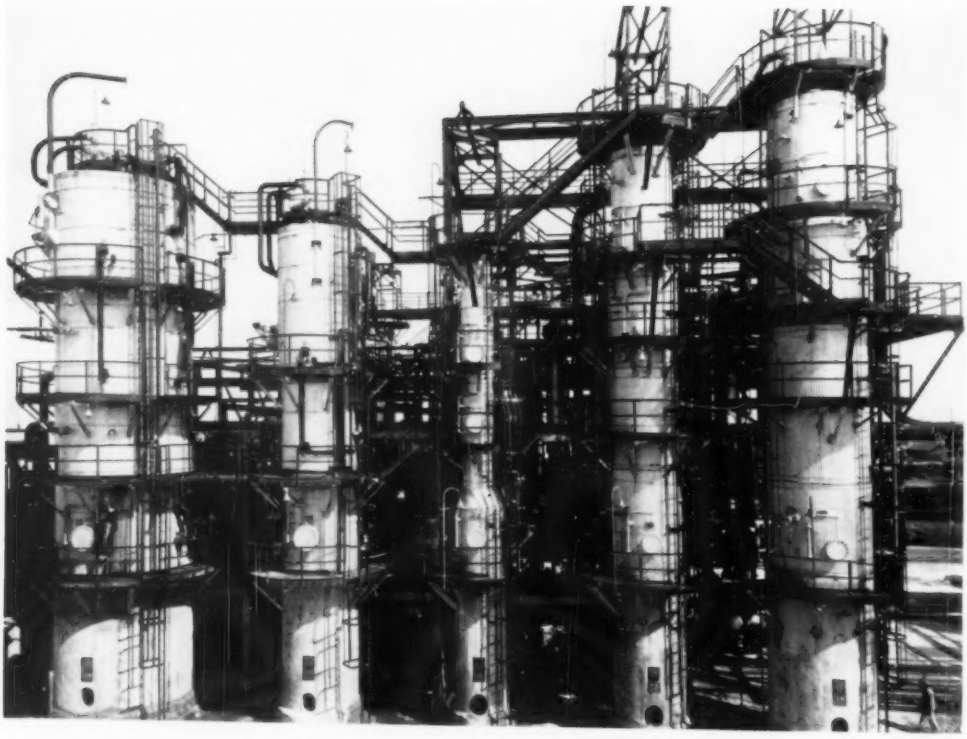

Figure 8 — Solvent strippers for a plant dewaxing unit.

oil (1) and pure diluent solvent (2) are mixed, chilled, and the wax slurry charged to a continuous rotary filter. The latter consists of a hollow perforated rotating drum, covered with filter cloth, and about half immersed in the wax slurry. By means of a rotary valve a vacuum is "pulled" on the submerged portion of the drum and the *filtrate* (4) consisting of dewaxed oil and solvent is thus drawn into the interior of the drum, leaving a layer of wax on the external surface of the filter. Cold fresh solvent (3) is sprayed on this wax layer near the end of the drum's revolution and drawn through the wax by the vacuum, thus washing off any filtrate that may have been trapped on the surface of the wax crystals. The washed wax cake is separated from the surface of the rotating drum by applying a positive pressure on its inner surface just before it reenters the slurry to pick up additional wax.

This early version of the solvent dewaxing process has given completely satisfactory service for many years and is still being used in some locations. However, further development work was undertaken to reduce costs. Calculations showed that the volume of *fresh* solvent required was one of the major costs, since all of it must be removed from the wax cake and dewaxed oil. However, the mixture charged to the filter must contain a certain minimum proportion of diluent solvent (2) to minimize the amount of oil trapped in the wax cake. In addition, some pure wash solvent (3) must be used to wash the wax cake. As illustrated in the right hand portion of schematic Figure 9, the improved version employs *two* filters and reduces pure solvent requirement by using filtrate (6) (which is practically pure solvent with only a small amount of dissolved oil) from the repulper filter for diluent solvent. In effect, the primary filter removes wax from the charge oil while the repulper receives and rewashes this wax, both to purify it and to recover any entrained oil. Thus, pure solvent (3) is first used to wash the wax in the repulper, then to dilute the waxy charge oil (1) before it enters the primary filter. As indicated by dashed lines, the primary filter may, or may not, subject its wax to a preliminary wash. The oil-solvent filtrate (4) from the primary filter and the wet wax (5) from the repulper are pumped to strippers which recover the solvent and deliver the desired dewaxed oil and wax.

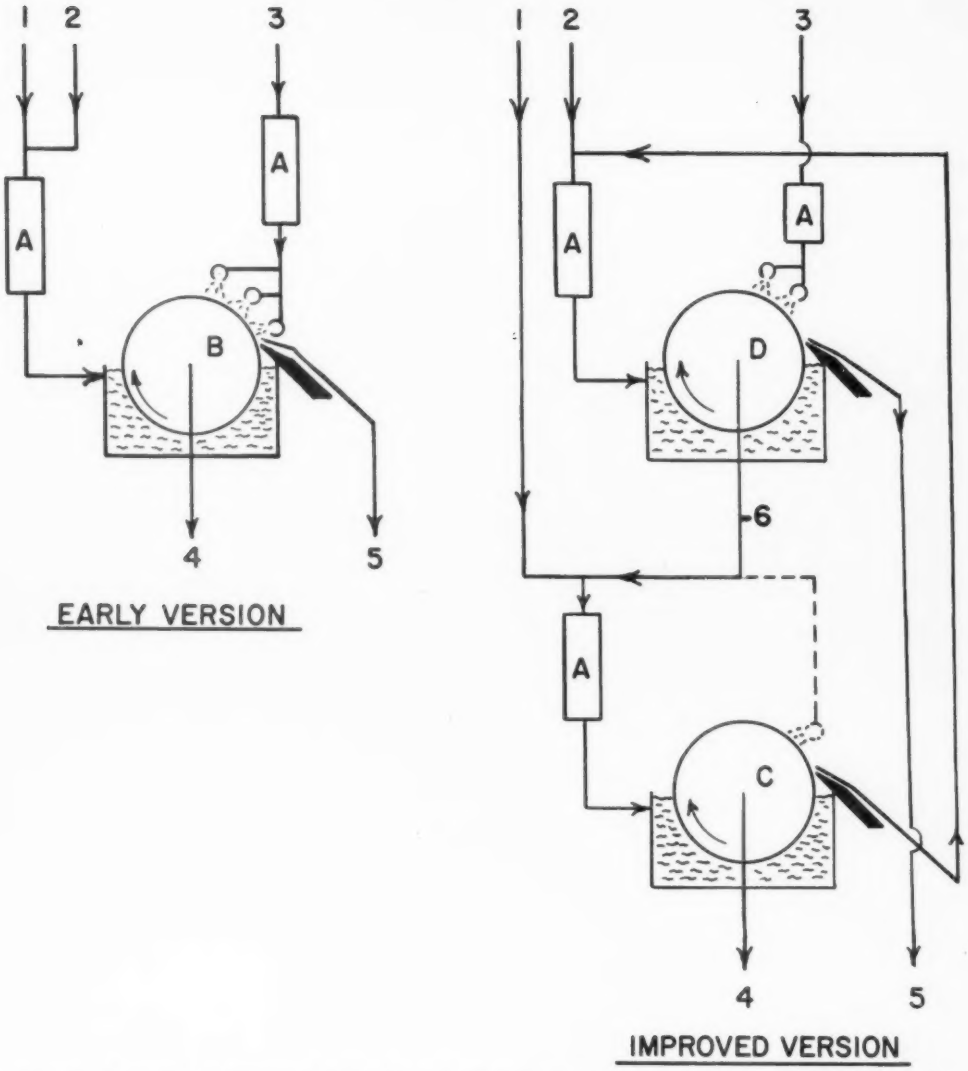

Figure 9 — Schematic flow diagrams illustrating the evolution of the solvent dewaxing process. EARLY VERSION: raw oil (1) is mixed with fresh solvent (2), chilled (A), the wax withdrawn on rotary vacuum filter (B), washed with fresh solvent (3) and removed (5). Solvent is removed and recovered in external stripper from the dewaxed oil-solvent solution (4) and washed wax (5) to produce dewaxed oil and wax. IMPROVED VERSION: raw oil (1) is mixed with used solvent (6), chilled (A), the wax withdrawn on rotary vacuum filter (C) with or without washing with used solvent. Wax from filter C is diluted with fresh solvent (2), chilled (A), withdrawn by rotary vacuum "repulper" filter (D), washed with chilled (A) fresh solvent (3) and removed (5). Solvent is removed and recovered in external stripper from dewaxed oil-solvent (4) and wax solvent solution (5) to produce dewaxed oil and wax.

NEW PROCESS DEVELOPMENT

In this era of expanding technology machines are constantly being developed which place greater demands on the oils used to lubricate them, consequently new oils must be continually developed to stay ahead of the machine's requirements. This may require that new processes be developed to make the oils. Also, existing processes eventually become obsolete or uneconomical in spite of continuing efforts to improve them, and new processes must be de-

veloped to replace them. A number of new lubricating oil manufacturing processes are currently being developed by the petroleum industry. A few such processes are briefly described below. Additional information on these processes can be obtained by perusal of the references shown.

Liquid Thermal Diffusion[6]

This process is designed to produce oils with exceptionally good viscosity-temperature properties. Solvent refined oils might be charged to this process for further improvement in this regard. Thermal diffusion has not yet been commercially adopted.

Catalytic Hydrogenation[7]

Even in its present state of development, this versatile process is already being used as a replacement for acid and clay treating. Acid and clay treating merely remove dark-colored unstable components from a base oil in the form of undesirable by-products. Hydrogenation converts the dark colored, unstable components of the base oil into more desirable materials with consequent decrease in processing losses. Operating costs are also lower for hydrogenation than for acid and clay treating. Because of these attractive features, the hydrogenation process is rapidly gaining commercial acceptance and several plants have been built recently.

[6] The Oil and Gas Journal—61 (March 27, 1961).
[7] The Oil and Gas Journal—81 (November 1, 1954).

Super-Refining[8]

The super-refining process (or sequence of processes) produces a product having unusually good volatility characteristics, viscosity-temperature properties, and oxidation stability. Processing is severe enough to remove completely all unsaturated hydrocarbons, and other nonhydrocarbon impurities, from the base oil. Solvent refining, acid and clay treating, and catalytic hydrogenation might be used, or various combinations of these processes. "Super-refined" products are being proposed for use in extraordinarily demanding applications, such as in advanced turbo-jet aircraft engines. As yet, this process has not been commercially adopted.

SUMMARY

The problems involved in manufacturing a complete line of quality lubricating oils are formidable. The necessary substitution of new crude oils for diminishing supplies of familiar ones requires an expert refiner to maintain a continuous crude evaluation program which enables him to select the most suitable crudes and the best methods of processing them into high quality lubricants. Continuous development is similarly necessary to improve the existing refining processes, while research works even further ahead of requirements to discover new ones.

[8] Preprints, General Papers, The American Chemical Society, Division of Petroleum Chemistry—59 (August, 1960).

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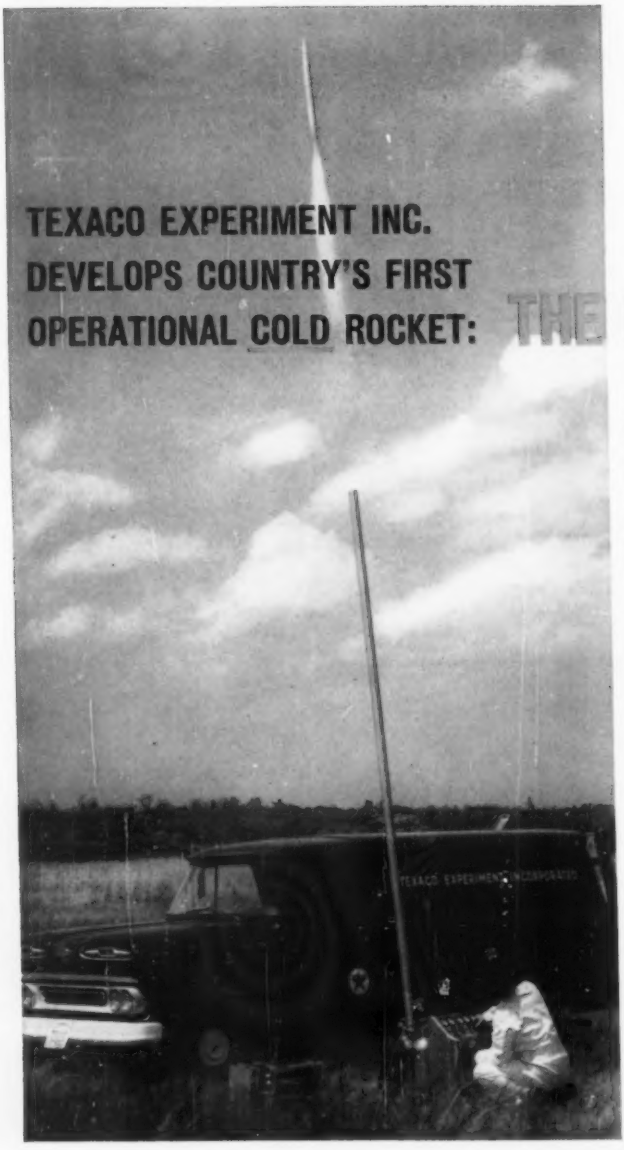

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